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Sex determination using mandibular ramus flexure: A preliminary study on Indian population

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ABSTRACT

Determination of sex by morphological assessment has been one of the oldest approaches in forensic anthropology. Loth and Henneberg[6] introduced a morphological trait "Mandibular Ramus Flexure" for sex identification with a high accuracy of 99% in African Blacks. However, the population specificity of sexually dimorphic features is well known. The purpose of this study is to test the reliability of this trait in Indian population. A total number of 112 adult mandibles (88 males and 24 females) were studied from the Department of Forensic Medicine, Institute of Medical Sciences, Banaras Hindu University, India. The mandibles were scored according to the original method by two observers in three different sessions. This was done to test inter and intra-observer errors in identifying the trait. The result shows that this trait can be used to diagnose sex with an average accuracy of upto 82%. Though, inter and intra-observer errors were present but could be minimized with extended practice. So, the trait has the potential to be relied upon as a single morphological trait for determination of sex in Indian population.

1. Introduction

The role of an anthropologist in a forensic setting is, to create a biological profile of unknown skeletal or decomposed remains, to arrive at conclusions regarding its age, sex, stature and ethnic background. Sex determination is one of the leading questions addressed when formulating the biological profile. Its knowledge refines focus of identification restricted to one sex only. The subsequent methods for age and stature estimation are also sex dependent as growth and maturation differs in sexes.

Traditionally, subjective visual assessments of sexually dimorphic features of the skull and pelvis are resorted to for sex identity. Morphological methods are not population specific, with suits application to fragmentary archaeological and forensic materials. Moreover, the method encapsulates morphological information that is difficult to quantify using standard anthropometric techniques.[1]

It has been stated that descriptive traits are more influential in sex determination from skulls than metric assessment of size and proportions.[2] Mandible is one of the most durable and dimorphic bone of the skull[3] and important for sex identification. Several studies evaluated the utility of sexually dimorphic human mandible using metric and morphological features.[3–10] It is found that dimorphism is generally more marked in mandibular ramus than in the mandibular body.[4] Mandibular ramus can differentiate between sexes as the process of mandibular development and masticatory forces are different for males and females which influence the shape of the ramus.[6,11]

Mandibular ramus flexure discovered by Loth and Henneberg[6] has drawn world-wide attention due to its exceptionally high accuracy in sex determination. The distinct flexure in the posterior border of ramus at the level of occlusal surface of the molars in adult males is not seen in females, if present, it was either above or below the occlusal surface. The authors claimed prediction accuracy of 90.6–99% in mandibles without loss of molar teeth. Thus far several studies have examined the usefulness of this method.[3,12–20] Koski[12] in radio-cephalometric study on white children (6–8 years) and young females (22–25 years), found no difference in sexes in

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Fig. 1. Male mandible showing ramus flexure (+1) score.

Fig. 3. Female mandible showing +1 score.

occurrence of mandibular ramus flexure. Similar observations were reported by Hu et al.[3] Other studies supported the findings of Loth and Henneberg in favor of the method.[14,19] The expression of ramus flexure has been suggested to be population specific and thus present investigation attempted to examine occurrence of this trait and its sex discriminating ability in Indian population.

2. Material and method

The samples were collected in the Department of Forensic Medicine, Institute of Medical Sciences, Banaras Hindu University, Varanasi, India. It comprised of 112 adult mandibles (88 males and 24 females) between the age group of 18–60 years, from forensic cases. Pathological mandibles having more than two ante-mortem molar teeth loss were excluded from the study.

The mandibles were scored according to the methodology of Loth and Henneberg.[6] Mandibles with ramus flexure at the level of occlusal surface were scored as +1 (Figs. 1 and 3), while straight ramus or flexure above or below the level of occlusal surface, were scored as −1 (Figs. 2, 4 and 5) and mandibles with no obvious flexure were scored as 0. For each mandible the scores for the right and left ramus were added. Mandibles with scores of 0 to +2 were identified as males and mandibles with scores of −1 and −2 as females. Left and right sides were scored separately at different time.

The ability of identifying a morphological trait by one or more observer is crucial to test its potential in determination of sex. Previous researchers reported difficulties in identifying the flexure, so inter and intra-observer errors were also calculated by Kappa statistics. For this, the mandibles were scored by two observers at different time and in three different sessions. The time gap between each session was two weeks to avoid any bias. The data was analyzed using SPSS statistical package.

3. Results

Table 1 presents a glance of previous researches on ramus flexure conducted on different populations employing different observation techniques.

The scores of ramus shape obtained by two observers (V.S and R.S) are presented in Table 2. Fifty two of male mandibles (59.1%) exhibited bilateral flexure i.e. scored '+2' whereas 18 (75%) female mandibles showed bilaterally straight ramus i.e. scored '−2'. Similar observations were obtained by second observer where 38 males (43.2%) showed bilateral flexure and 17 females (70.8%) showed bilaterally straight flexure.

The predictive accuracy for males and females is presented in Table 3. It is obvious from this table that 17 of 88 males have a female shape (−1 and −2 score) and 3 of 24 females have male shape (0, +1 and +2 score) thus only 82.1% mandibles (80.7% males and 87.5% females) were correctly assigned by first observer. Second observer found slightly lower accuracy and correctly identified 77.7% mandibles (males 77.2% and females 79%).

Fig. 2. Female mandible showing straight border (−1) score.

Fig. 4. Male mandible showing straight ramus (−1) score.

Fig. 5. Female mandible with −1 score where the curve is below occusals.

Inter and Intra-observer agreement is measured using Cohen's Kappa statistics.[21,22] In Table 4 the intra-observer agreement between three sessions of both the observers is given. *K* values clearly show moderate to good agreement for both observers (0.579–0.758 and 0.579–0.739 respectively) in three different sessions.

The inter-observer agreement in 3 sessions is given in Table 5. *K* values indicate moderate to very good agreement (0.509–0.860). It shows that agreement improved as both the observers get more and more acquainted with the trait.

4. Disscussion

A number of morphological features of mandible like gonial flare, chin shape, shape of lower border have been studied for sexual dimorphism among which mandibular ramus flexure has gained favor for accuracy.[19,23] Population specific nature of the mandibular ramus flexure has been suggested by previous researchers so we have verified the expression of the trait and its predictive accuracy in sex determination among North Indian population.[16,17,19,24]

The sexual variations in mandibles may bear genetic, hormonal or environmental influences.[4,6,9,14,25] Since mandible is the last skull bone to cease growth,[26,27] it is sensitive to adolescent growth spurt.[28] Due to the effect of estrogen, epiphyseal maturation and skeletal mineralization, mandibular growth becomes stable in females at the age of around 14, while it continues for two more years in males, making the flexure more obvious.[14] Relatively, weaker muscle forces during mastication, may also contribute to small sized mandibles in females.

Table 2
Distribution of ramus shape scores by sex in the total sample.

Sex	*N*	−2	−1	0	+1	+2
1st observer						
Males	88	15	2	15	4	52
Females	24	18	3	2	0	1
Total	112	33	5	17	4	53
2nd observer						
Males	88	15	5	17	13	38
Females	24	17	2	3	0	2
Total	112	32	4	20	13	40

The results show that there is significant difference in the shape of male and female mandibles ($p < .001$). The trait can correctly diagnose 77.2–80.7% males and 79.2–87.5% females. The overall predictive accuracy was 77.7–82.1% which is much lower than claimed by Loth and Henneberg.[6]

In present study, both observers identified females more accurately by observing posterior ramus border (Table 3). Hill[17] and Ottele et al.[20] however opined greater variability of shape of female mandible. We found that most of the female mandibles have posterior border either straight or if any flexure present, it was above the occlusal level near the condylar neck.[14] However, Koski[12] found straight ramus-condyle line to be rare in females and young adults.

Donnelly et al.[13] and Hill[17] were convinced of dimorphic value of flexure in males and even score '0', indicating only one sided findings to be designating males. In present study exclusion of male samples with '0' score undermined accuracy of detecting males to 63.6% (56 males) and 57.9% (51 males) by two independent observers (Table 2).

Morphological features get confounded by inter-observer differences and difficulties in standardization.[21] Very high degree of intra and inter-observer errors were reported by Donnelly et al.[13] and Grottenthaler et al.[18] in identifying the flexure. Thus they considered association between ramus flexure and sex to be weak.

Table 1
Observations of previous researches conducted on various populations.

Author & year	Ethnic origin	Sample size		Accuracy %		Overall accuracy %
		Male	Female	Male	female	
Loth& Henneberg (1996)	Black	48	48	91.7	89.6	94.2
	White	47	38	91.5	92.1	
	Amerindians	32	34	93.8	91.2	
Koski (1996)	White females and children[b]	–	–	–	–	No difference in flexure
Mieke (1996)	West Flores population[b]	75	75	95	88	–
Gunay et al. (1997)	Turkish population	16	7	87.5	57.1	73.3
Indrayana et al. (1998)	Javanese population[b]	70	65	90	94	–
Donnelly et al. (1998)	American black & White & Amerindian	56	40	80.4	37.5	62.5
Haun (2000)	North Eastern Iran[a]	28	27	92.9	63	78.2
Hill (2000)	Europian-American	65	28	89.2	60.7	79.1
	African-American	38	27	94.7	51.9	
Coqueugniot et al. (2000)	Isreal & Europe[a]	5	1			Not reliable
Grottenthelar et al. (2002)	German population	122	31	65.6	32.3	58.8
Balci et al. (2005)	Turkish population	95	25	92.6	60.0	85.8
Ottele et al. (2005)	Black population[c]	43	28	69.6	67.8	–
Hu et al. (2006)	Koreans	74	33			No difference in flexure

[a] Archaeological samples.
[b] cephalograms.
[c] geometric morphometrics study.

Table 3
Overall accuracy of ramus shape as an indicator of sex in the total sample (According to Loth &Henneberg).

Sex	N	−1 & −2		0, +1 & +2		Accuracy by sex %
		n	%	n	%	
1st Observer						
Males	88	17	44.7	71	95.9	80.7
Females	24	21	55.3	3	4.1	87.5
	112	38	100	74	100	82.1
2nd observer						
Males	88	20	51.3	68	93.2	77.2
Females	24	19	48.7	5	6.8	79.0
	112	39	100	73	100	77.7

Table 4
Intra-observer agreement in three sessions.

Sessions	Observer	Kappa values	Interpretation
I/II	1st Observer	.709	Substantial agreement
I/III		.758	Substantial agreement
II/III		.579	Moderate agreement
I/II	2nd Observer	.522	Moderate agreement
I/III		.739	Substantial agreement
II/III		.579	Moderate agreement

Table 5
Inter-observer agreement for ramus flexure – comparison of Kappa values.

Observer	Session	Kappa	Interpretation
I/II	1st	.597	Moderate agreement
I/II	2nd	.509	Moderate agreement
I/II	3rd	.860	Almost perfect agreement

During this study inter-observer differences did occur with regard to identifying the level of the flexure but not in identifying very presence. The same is likely to diminish with experience. Inter-observer agreement increases from moderate in first session to almost perfect agreement in third session as seen in Table 5.It is suggested that the gonial angle and condylar angle should be clearly located while identifying the flexure.

Intra-observer differences in three sessions were negligible (Table 4). The *k* values which increased from moderate in 1st session to very good agreement in 3rd session, indicating scope for eliminating intra-observer errors.

The discrepancies in the studies may result from differences of selected population. It is well known that sexual dimorphism is expressed more distinctly when there are better living conditions and health status of the given population.[29,30] Consequently, it is of low degree in Indian population due to existing malnutrition.[31–33] Further, socioeconomic factors (nutrition, chewing habits, occupation etc) may contribute to expression of sexual dimorphism in case of North Indian population.

The other probable cause may be related to small sample size, unequal male and female ratio and sample heterogeneity (forensic sample). Cunha and Van Vark showed that such sample heterogeneity significantly contributes to a reduction in sexual dimorphism.[34] Thus traits that are sexually dimorphic in one population may be much less so in another due to contributive effect of several factors.

5. Conclusion

The trait has significant value in identifying sex with quite good predictive accuracy in Indian population and has practical application for actual forensic casework. The mandibles with “0” score can be suggested to be removed to avoid bias in results. Though inter and intra-observer errors do exist, it decreases with experience, so well acquaintance with the trait using known samples is suggested.

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Conflict of interest
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References

1. Walker PL. Sexing skulls using discriminant function analysis of visually assessed traits. *Am J Phys Anthropol* 2008;**136**:39–50.
2. Celbis O, Iscan MY, Soysal Z, Cagdir S. Sexual diagnosis of the glabellar region. *Leg Med (Tokyo)* 2001;**3**(3):162–70.
3. Hu KS, Koh KS, Han SH, Shin KJ, Kim HJ. Sex determination using non metric characteristics of the mandible in Koreans. *J Forensic Sci* 2006;**51**(6):1376–82.
4. Humphrey LT, Dean MC, Stringer CB. Morphological variation in great ape and modern human mandibles. *J Anat* 1999;**195**:451–513.
5. Giles E. Sex determination by discriminant function analysis of the mandible. *Am J Phys Anthropol* 1964;**22**:129–35.
6. Loth SR, Henneberg M. Mandibular ramus.flexure: a new morphologic indicator of sexual dimorphism in the human skeleton. *Am J Phys Anthropol* 1996;**99**(3):473–85.
7. Steyn M, Iscan MY. Sexual dimorphism in the crania and mandibles of South African Whites. *Forensic Sci Int* 1998;**98**(1–2):9–16.
8. Franklin D, Higgins PO, Oxnard CE, Dadour I. Determination of sex in South African Blacks by discriminant function analysis of mandibular linear dimensions: a preliminary investigation using the Zulu local population. *Forensic Sci Med Pathol* 2006;**2**(4):263–8.
9. Vodanovic M, Dumancic J, Demo Z, Mihelic D. Determination of sex by discriminant function analysis of mandibles from two Croatian archaeological sites. *Acta Stomatol Croat* 2006;**40**(3):263–77.
10. Dayal MR, Spocter MA, Bidmos MA. An assessment of sex using the skull of black South Africans by discriminant function analysis. *Homo* 2008;**59**(3):209–21.
11. Loth SR, Henneberg M. Sexually dimorphic mandibular morphology in the first few years of life. *Am J Phy Anthropol* 2001;**115**(2):179–86.
12. Koski K. Mandibular ramus flexure: indicator of sexual dimorphism? *Am J Phys Anthropol* 1996;**101**(4):545–6.
13. Donnelly S, Hens SM, Rogers NL, Schneider KL. A blind test mandibular ramus fexure as a morphological indicator of sexual dimorphism in the human skeleton. *Am J Phys Anthropol* 1998;**17**:363–6.
14. Indryana NS, Glinka J, Mieke S. Mandibular ramus fexure in an Indonesion population. *Am J Phys Anthropol* 1998;**105**:89–90.
15. Coqueugniot H, Tillier AM, Bruzek J. Mandibular ramus posterior flexure: a sex indicator in Homo sapiens fossil Homonids? *Int J Osteoarchaeol* 2000;**10**:426–31.
16. Huan SJ. Brief communication: a study of the predictive accuracy of mandibular ramus flexure as singular morphologic indicator of sex in an archaeological sample. *Am J Phys Anthropol* 2000;**111**:429–32.
17. Hill CA. Technical note: evaluating mandibular ramus fexure as a morphological indicator of sex. *Am J Phys Anthropol* 2000;**111**:572–7.
18. Grottenthaler AK, Lobig F, Stock F. Mandibular ramus flexure and gonial eversion as morphological indicators of sex. *Homo* 2002;**53**:97–111.
19. Balci Y, Yavuz MF, Cagdir S. Predictive accuracy of sexing the mandible by ramus flexure. *Homo* 2005;**55**:229–37.
20. Oettle AC, Pretorius E, Steyn M. Geometric morphometric analysis of mandibular ramus flexure. *Am J Phys Anthropol* 2005;**128**(3):623–9 [Abstract].
21. Fleiss J. *Statistical methods for rates and proportions*. 2nd ed. New York: John Wiley and Sons; 1981.
22. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;**33**:159–74.
23. Muller EK. A test of the accuracy of techniques used to determine sex in the mandible. *Am J Phys Anthropol Suppl* 1998;**26**:168–9.

24. Loth SR, Henneberg M. Mandibular ramus flexure is a good indicator of sexual dimorphism. *Am J Phys Anthropol* 1997;**105**(1):91–2.
25. Nakata M. Masticatory function and its effects on general health. *Intl Dent J* 1998;**48**:540–8.
26. Enlow DH. *The human face: an account of the postnatal growth and development of the craniofacial skeleton*. New York: Hoeber Medical Division, Harper & Row Publishers; 1968.
27. Rogers TL. Determination of human remains through cranial morphology. *J Forensic Sci* 2005;**50**(3):493–500.
28. Rosas A, Bastir M, Maza M, de Castro JMB. Sexual dimorphism in the Atapuerca-SH homonids: the evidence from the mandibles. *J Hum Evol* 2002;**42**(2):451–74.
29. Frayer DW, Wolpoff MH. Sexual dimorphism. *Annu Rev Anthropol* 1985;**14**:429–73.
30. Lazenby RA. Sex dimorphism and bilateral asymmetry: modeling developmental instability and functional adaptation. *Am J Phys Anthropo* 2001;**Suppl. 32**:96.
31. Bairagi R. A comparison of five anthropometric indices for identifying factors of malnutrition. *Am J Epidemiol* 1987;**126**(2):258–67.
32. Walia BNS, Singh S. Protein energy malnutrition. *Curr Paediatr* 1995;**5**(1):43–8.
33. Abbasi K. The World Bank and world health focus on South Asia—II: India and Pakistan. *BMJ* 1999;**318**:1132–5.
34. Kemkes A, Gobel T. Metric assessment of the “mastoid triangle” for sex determination: a validation study. *J Forensic Sci* 2006;**51**:985–9.